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Mineralogy of Deep-Sea Sediments Along the Murray Fracture Zone[1]

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ABSTRACT: Semiquantitative X-ray diffraction mineralogical studies show that deep-sea brown clays from 23 cores and a long core from Deep Sea Drilling Project Site 39 along the Murray Fracture Zone and in the vicinity of Necker ridge consist of the minerals quartz, plagioclase, mica, chlorite, kaolinite, montmorillonite, phillipsite, and goethite, and minor amounts of dolomite, aragonite, calcite, barite, and augite. According to mineral assemblages, five suites are recognized—eolian, detrital, authigenic, biogenic, and hydrothermal.

MATERIALS AND METHODS

THE MURRAY FRACTURE ZONE is a prominent east–west trending fracture across the northeastern portion of the Pacific basin. Menard (1964) reported the fault scarp with the upthrown side to the south; the crustal thickness is about 2 km less on the south than on the north side. Volcanoes are common south of the Murray Fracture Zone, and deep-sea fans and plains are abundant to the north. Thin sedimentary layers, approximately 50 m thick, were noted along the Murray Fracture Zone (Malahoff and Woollard 1971). Twenty-three gravity and free-fall cores were taken by Malahoff during 1966 for paleomagnetic studies (Malahoff and Hammond 1971). Most of the cores are typical deep-sea brown clay (Andrews et al. 1970).

This study investigates the mineral assemblages of sediments from the Murray Fracture Zone and the vicinity of Necker ridge to determine the sources of these sediments. Cores collected along and adjacent to the Murray Fracture Zone (MFZ series, Figure 1) were used. In addition, samples from Deep Sea Drilling Project (DSDP) Hole 39 along the Murray Fracture Zone were used to study the vertical distribution of the mineral assemblages.

Semiquantitative X-ray diffraction analysis of mineral composition in bulk samples by the method of Rex (1969) and Fan and Rex (1972) was used to determine the relative abundances of minerals by means of peak height calibration factors for the various phases.

RESULTS

The mineral assemblages of the bulk samples of the MFZ cores and DSDP Hole 39 are shown in Tables 1 and 2, respectively. In MFZ cores, quartz, mica, and plagioclase are the predominant minerals of the bulk fraction; chlorite, kaolinite, and montmorillonite are also present in most samples. Large concentrations of phillipsite occur usually near the top of the cores.

Unusual carbonate mineral assemblages—aragonite, calcite, and dolomite—occurred in the brown clays at site MFZ 3–5 (Figure 1) at a depth of 3250 m. The aragonite and calcite contents in the 800-cm core decrease with depth, whereas the dolomite content increases (from 6 to 31 percent) with depth. Scanning electron micrograph studies of the deep-sea carbonates indicate the presence of biogenic remains (calcite and aragonite) and rhombs (dolomite, Figure 2).

The DSDP Hole 39 samples consist largely of mica, quartz, and plagioclase, and minor amounts of chlorite, kaolinite, and montmorillonite. Large concentrations of phillip-

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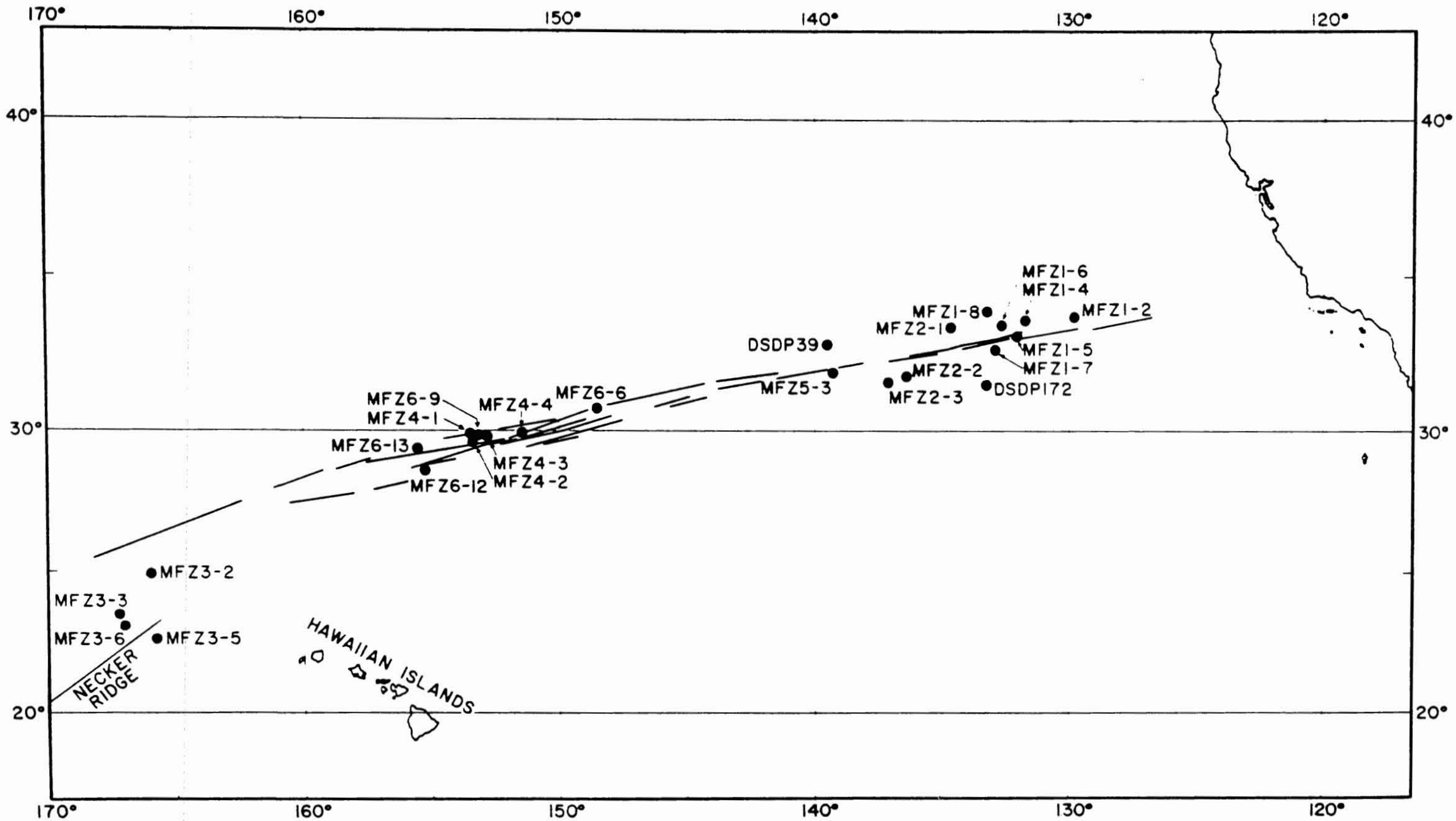

FIGURE 1. Location of Murray Fracture Zone cores.

TABLE 1

MINERALOGY OF BULK SAMPLES FROM MFZ CORES

CORE NO.*	LATITUDE (N)	LONGITUDE (W)	WATER DEPTH (m)	CORE DEPTH (cm)	MINERALS (WEIGHT %)											
					QUAR.	PLAG.	MICA	CHLOR.	KAOL.	MONT.	PHIL.	DOLO.	ARAG.	CALC.	BARI.	AUG.
MFZ 1-2	33°46.5′	129°40.0′	4,660	0	21.9	—	40.5	5.0	—	4.4	28.2	—	—	—	—	—
MFZ 1-4	33°35.5′	131°42.5′	5,000	0	20.1	—	42.2	4.6	—	2.7	30.3	—	—	—	—	—
MFZ 1-4	33°35.5′	131°42.5′	5,000	108	23.3	14.5	46.8	6.2	—	4.3	—	—	—	—	—	—
MFZ 1-5	33°02.0′	132°03.8′	4,460	0	26.8	14.7	42.8	5.9	1.3	8.6	—	—	—	—	—	—
MFZ 1-6	33°31.0′	132°37.5′	5,140	0	21.0	—	41.1	5.2	—	1.4	31.2	—	—	—	—	—
MFZ 1-6	33°31.0′	132°37.5′	5,140	53	23.3	11.9	46.1	4.0	4.8	9.7	—	—	—	—	—	—
MFZ 1-7	32°38.5′	132°54.5′	4,640	0	25.1	14.5	44.1	7.0	0.2	9.1	—	—	—	—	—	—
MFZ 1-7	32°38.5′	132°54.5′	4,640	26	24.0	15.1	40.2	5.5	2.4	12.6	—	—	—	—	—	—
MFZ 1-7	32°38.5′	132°54.5′	4,640	76	24.9	16.8	40.2	5.6	1.9	10.6	—	—	—	—	—	—
MFZ 1-8	33°50.0′	133°10.5′	5,140	0	33.6	15.8	42.5	7.4	0.7	—	—	—	—	—	—	—
MFZ 1-8	33°50.0′	133°10.5′	5,140	14.5	24.3	12.1	50.2	7.1	0.9	5.5	—	—	—	—	—	—
MFZ 1-8	33°50.0′	133°10.5′	5,140	66	22.8	11.9	48.7	5.2	3.0	8.3	—	—	—	—	—	—
MFZ 1-8	33°50.0′	133°10.5′	5,140	119	26.0	13.2	46.2	6.1	1.6	6.8	—	—	—	—	—	—
MFZ 1-8	33°50.0′	133°10.5′	5,140	169	27.5	13.9	44.1	4.8	2.5	7.3	—	—	—	—	—	—
MFZ 1-8	33°50.0′	133°10.5′	5,140	219	27.1	13.7	45.9	6.1	1.8	5.4	—	—	—	—	—	—
MFZ 2-1	33°18.8′	134°39.0′	4,840	0	30.5	12.9	44.1	6.6	1.3	4.5	—	—	—	—	—	—
MFZ 2-1	33°18.8′	134°39.0′	4,840	55	28.6	13.8	45.9	6.4	—	5.2	—	—	—	—	—	—
MFZ 2-1	33°18.8′	134°39.0′	4,840	105	29.2	14.1	48.7	6.4	—	1.6	—	—	—	—	—	—
MFZ 2-2	31°46.8′	136°22.5′	4,550	0	21.8	—	39.7	5.1	—	1.2	32.2	—	—	—	—	—
MFZ 2-2	31°46.8′	136°22.5′	4,550	106	26.5	15.6	45.1	5.2	1.7	5.8	—	—	—	—	—	—
MFZ 2-3	31°31.0′	137°02.8′	5,225	0	20.6	—	43.1	4.9	—	1.6	29.3	—	—	—	—	—
MFZ 2-3	31°31.0′	137°02.8′	5,225	25	27.2	12.2	47.7	6.3	1.4	5.6	—	—	—	—	—	—
MFZ 2-3	31°31.0′	137°02.8′	5,225	55	26.3	12.7	44.0	7.3	—	9.7	—	—	—	—	—	—
MFZ 3-2	24°58.0′	165°55.0′	5,100	0	20.3	—	42.0	5.1	—	—	32.6	—	—	—	—	—
MFZ 3-3	23°32.0′	167°05.5′	3,100	10	24.4	9.8	54.0	6.2	2.7	—	—	2.8	—	—	—	—
MFZ 3-5	22°41.0′	165°48.0′	3,250	0	10.4	21.2	26.9	2.4	3.8	1.9	—	6.1	19.2	8.3	—	—
MFZ 3-5	22°41.0′	165°48.0′	3,250	3	16.9	30.4	38.9	3.7	4.0	4.0	—	—	—	—	—	2.1
MFZ 3-5	22°41.0′	165°48.0′	3,250	53	18.9	21.2	—	3.4	11.0	4.8	—	31.2	6.0	3.3	—	—
MFZ 3-6	23°07.5′	167°00.0′	3,000	0	19.0	—	40.7	5.3	—	—	33.6	—	—	1.4	—	—
MFZ 3-6	23°07.5′	167°00.0′	3,000	16	9.8	3.8	25.9	2.5	2.1	2.0	—	—	23.1	30.7	—	—
MFZ 3-6	23°07.5′	167°00.0′	3,000	66	23.0	20.5	46.5	4.7	2.2	2.1	—	—	—	—	—	—
MFZ 3-6	23°07.5′	167°00.0′	—	116	25.1	10.5	53.5	6.4	2.1	2.3	—	—	—	—	—	—
MFZ 3-6	23°07.5′	167°00.0′	—	166	24.8	10.7	52.7	6.1	2.6	2.1	—	—	—	—	—	—
MFZ 3-6	23°07.5′	167°00.0′	—	216	25.8	11.9	50.8	1.7	6.3	3.5	—	—	—	—	—	—

TABLE 1 (*Cont.*)

MINERALOGY OF BULK SAMPLES FROM MFZ CORES

CORE NO.*	LATITUDE (N)	LONGITUDE (W)	WATER DEPTH (m)	CORE DEPTH (cm)	MINERALS (WEIGHT %)											
					QUAR.	PLAG.	MICA	CHLOR.	KAOL.	MONT.	PHIL.	DOLO.	ARAG.	CALC.	BARI.	AUG.
MFZ 4-1	29°54.5′	153°25.0′	5,109	0	27.5	11.6	52.8	7.2	0.9	—	—	—	—	—	—	—
MFZ 4-2	29°40.2′	153°23.5′	6,182	0	19.1	—	42.8	5.2	—	—	33.0	—	—	—	—	—
MFZ 4-3	29°48.5′	152°49.5′	5,927	0	26.3	11.1	51.0	5.9	2.5	3.2	—	—	—	—	—	—
MFZ 4-3	29°48.5′	152°49.5′	5,927	97	26.4	12.5	49.2	4.3	2.9	4.8	—	—	—	—	—	—
MFZ 4-4	29°58.0′	151°22.3′	5,600	0	25.5	10.1	55.5	6.5	2.5	—	—	—	—	—	—	—
MFZ 4-4	29°58.0′	151°22.3′	5,600	8	27.7	11.2	50.5	6.1	2.3	2.2	—	—	—	—	—	—
MFZ 5-3	31°51.5′	139°14.5′	4,800	5	23.9	11.3	51.6	4.2	4.8	4.2	—	—	—	—	—	—
MFZ 5-3	31°51.5′	139°14.5′	4,800	45	24.1	10.3	48.6	4.3	3.2	9.5	—	—	—	—	—	—
MFZ 5-3	31°51.5′	139°14.5′	4,800	77	28.2	13.9	43.7	4.7	2.5	7.1	—	—	—	—	—	—
MFZ 5-3	31°51.5′	139°14.5′	4,800	352	7.1	—	16.8	—	—	10.4	63.6	—	—	—	2.1	—
MFZ 6-6	30°42.3′	148°16.9′	5,500	15	28.0	11.2	53.1	7.5	0.2	—	—	—	—	—	—	—
MFZ 6-6	30°42.3′	148°16.9′	5,500	65	28.3	11.6	48.3	4.5	4.0	3.3	—	—	—	—	—	—
MFZ 6-6	30°42.3′	148°16.9′	5,500	70	27.1	11.6	50.5	4.5	2.8	3.9	—	—	—	—	—	—
MFZ 6-6	30°42.3′	148°16.9′	5,500	163	27.1	11.2	50.5	4.5	2.8	3.9	—	—	—	—	—	—
MFZ 6-6	30°42.3′	148°16.9′	5,500	186	27.7	11.2	53.0	7.5	—	0.7	—	—	—	—	—	—
MFZ 6-9	29°51.3′	153°10.1′	5,192	10	26.7	10.6	50.5	5.8	2.4	3.9	—	—	—	—	—	—
MFZ 6-9	29°51.3′	153°10.1′	5,192	160	21.9	10.2	51.2	4.1	2.6	10.0	—	—	—	—	—	—
MFZ 6-12	28°36.4′	155°18.4′	5,160	5	28.2	12.4	50.1	7.7	0.1	1.5	—	—	—	—	—	—
MFZ 6-12	28°36.4′	155°18.4′	5,160	55	27.8	12.2	51.4	6.1	1.1	1.4	—	—	—	—	—	—
MFZ 6-12	28°36.4′	155°18.4′	5,160	105	28.5	12.1	50.8	7.8	0.1	0.6	—	—	—	—	—	—
MFZ 6-12	28°36.4′	155°18.4′	5,160	155	28.9	11.8	51.1	6.3	0.4	1.5	—	—	—	—	—	—
MFZ 6-12	28°36.4′	155°18.4′	5,160	295	28.6	6.5	54.6	8.6	—	1.6	—	—	—	—	—	—
MFZ 6-12	28°36.4′	155°18.4′	5,160	395	26.3	13.4	47.4	5.8	1.1	3.1	—	—	—	2.9	—	—
MFZ 6-12	28°36.4′	155°18.4′	5,160	445	22.5	11.4	51.2	5.1	1.6	8.2	—	—	—	—	—	—
MFZ 6-12	28°36.4′	155°18.4′	5,160	545	28.8	15.1	49.1	6.5	—	0.5	—	—	—	—	—	—
MFZ 6-13	29°21.6′	155°34.2′	5,625	30	27.8	12.2	49.5	6.1	1.2	3.2	—	—	—	—	—	—
MFZ 6-13	29°21.6′	155°34.2′	5,625	80	20.4	20.9	29.9	2.4	11.2	15.2	—	—	—	—	—	—
MFZ 6-13	29°21.6′	155°34.2′	5,625	60	1.0	—	7.8	—	—	2.3	88.9	—	—	—	—	—
MFZ 6-13	29°21.6′	155°34.2′	5,625	105	6.8	—	38.7	—	—	2.3	52.2	—	—	—	—	—

*MFZ 3–2 through MFZ 3–6 were collected during Murray Fracture Cruise 19; these samples from this site (near Necker ridge) are not considered as part of the Murray Fracture Zone.

TABLE 2

MINERALOGY OF BULK SAMPLES FROM DEEP-SEA DRILLING PROJECT HOLE 39

SAMPLE	CORE DEPTH (cm)	MINERALS (weight %) QUAR.	PLAG.	MICA	CHLOR.	KAOL.	MONT.	PHIL.	K-fe.	GOETH.
1-1	67–68	28.7	12.2	50.9	7.0	1.1	—	—	—	—
1-2	41–42	26.5	11.8	50.5	6.2	1.5	3.5	—	—	—
1-2	142–143	20.9	13.7	44.0	5.0	7.8	8.6	—	—	—
1-3	19–20	26.1	15.8	43.8	5.2	4.9	4.1	—	—	—
1-3	62–63	27.8	11.8	47.9	4.8	3.5	4.2	—	—	—
1-4	10–11	20.7	—	—	—	16.6	—	—	23.3	39.5
1-4	29–30	12.6	12.4	23.8	—	14.9	10.8	25.6	—	—
1-4	45–46	16.9	7.5	26.9	3.1	—	2.2	43.4	—	—
1-4	90–91	11.7	10.9	24.4	—	12.9	—	—	15.5	24.5
1-5	33–34	6.4	—	9.9	—	—	—	83.6	—	—
1-5	36–37	8.8	26.6	20.1	—	—	—	44.5	—	—
1-6	12–13	2.4	—	12.4	—	—	—	85.2	—	—
2-1	78–79	3.0	19.0	9.5	—	—	—	52.2	—	16.3
2-1	109–110	24.9	14.1	46.4	5.5	5.6	3.5	—	—	—
2-2	49–50	6.5	—	16.1	—	—	19.4	41.7	—	16.3
2-3	60–61	11.9	17.8	20.1	—	20.8	—	—	16.1	13.2
2-5	70–71	18.1	—	—	—	16.5	—	—	29.5	35.8
2-6	10–11	25.4	—	—	—	—	—	—	—	74.6
2-8	65–66	13.3	—	26.6	—	11.8	—	—	19.0	29.4

NOTE: The original X-ray mineralogy was reported by Rex and Murray (1970). The samples were rerun and the semiquantitative calculations were based on the modified factors (Fan and Rex 1972). Water depth, 4929 m; latitude 32°48.28′N; longitude, 139°34.29′W.

site are present in half of the samples examined. K-Feldspar and goethite occur where phillipsite is absent.

The mineral assemblages of DSDP Hole 39 and the MFZ bulk samples can be classified into five suites: (1) eolian—quartz and mica; (2) detrital—plagioclase, augite, kaolinite, montmorillonite, chlorite; (3) authigenic—phillipsite, montmorillonite, barite, goethite, and dolomite; (4) biogenic—calcite and aragonite; and (5) hydrothermal—goethite, kaolinite, K-feldspar, and dolomite.

DISCUSSION

Rex and Goldberg (1958), Griffin and Goldberg (1963), and Rafer et al. (1969) showed the abundant quartz content in the pelagic sediments in the Pacific, especially between 20 and 40° N. Rex et al. (1969) used oxygen isotopic studies to demonstrate that the fine-grained quartz in Hawaiian soils and in Pacific pelagic sediments is eolian. The high mica content in the same high-quartz region was reported by Griffin, Windom, and Goldberg (1968). Fan (1971) showed the high concentration of mica around the Hawaiian Archipelago. Dymond, Biscaye, and Rex (1974) used radiometric dating to demonstrate that the 250 million-year-old mica of the Hawaiian soils is eolian. A scatter plot of quartz versus mica of the DSDP Hole 39 and MFZ cores (Figure 3) shows that the Paleocene assemblages are strikingly different from the Neogene assemblages. The increase of mica and quartz in the younger sediments is probably due to an increase in windblown silt from unweathered glacial rock flour. Jacobs (1970) and Jacobs and Hays (1972), in their studies of Cretaceous and Tertiary deep-sea sediments of the North American Basin and the eastern Pacific, also noted the higher mica content in the Pleistocene ocean sediments. Heath (1969) found that Early and Middle Tertiary deep-sea carbonates from the equatorial Pacific differ from younger deposits in both texture and depth distribution.

The deep-sea chlorite is generally considered detrital in origin (Griffin et al. 1968). The chlorite content ranges from 0 to 8 per-

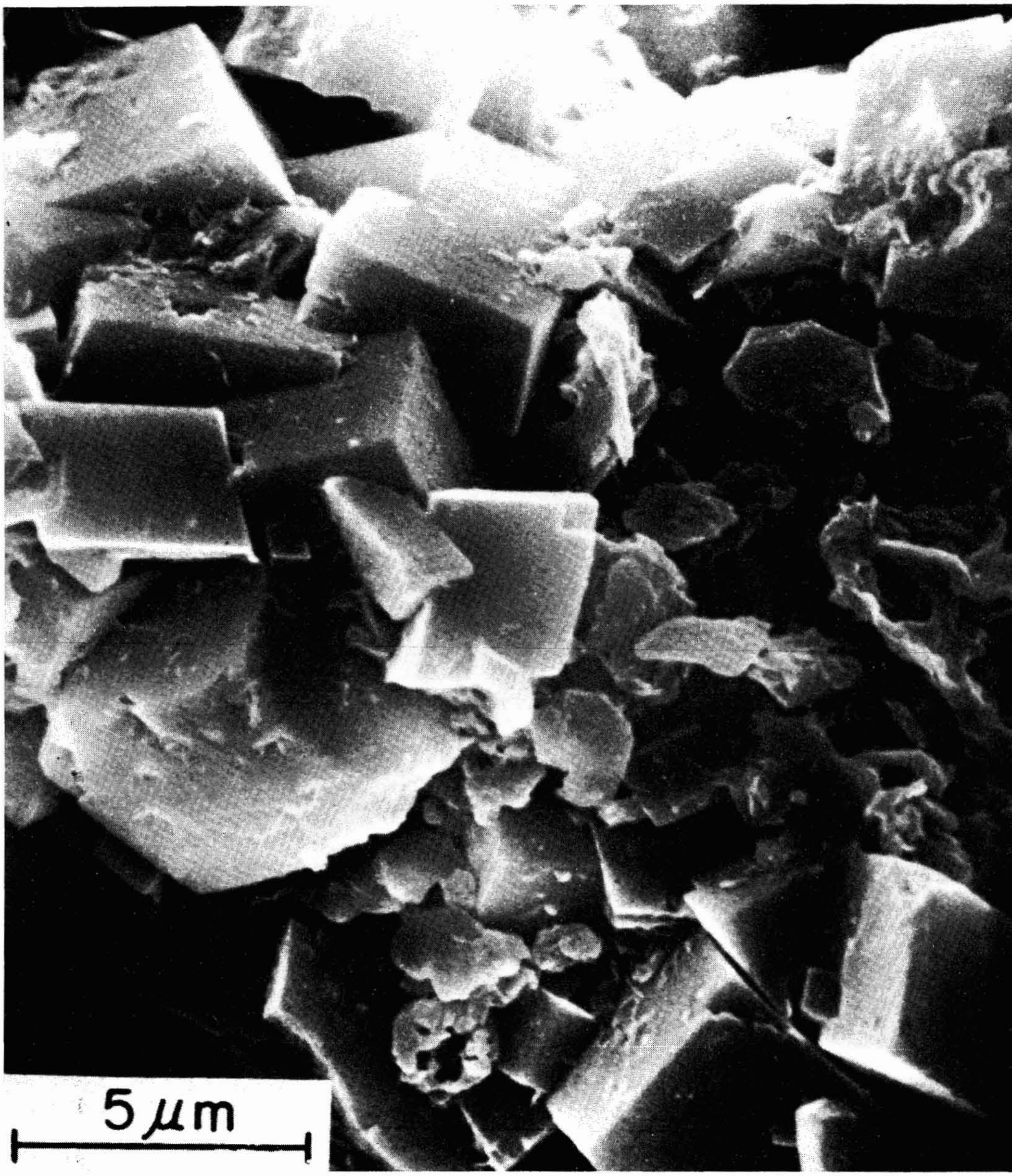

FIGURE 2. Scanning electron micrograph of dolomite from 53-cm interval of core MFZ 3–5.

cent in the area studied. Its variability is independent of other minerals.

Kaolinite is generally considered to be a detrital mineral resulting from the soil-forming process. The kaolinite content in the area studied ranges from 0 to 15 percent with the exception of six samples. The higher concentrations of kaolinite are correlated with the presence of goethite and K-feldspar of authigenic origin.

Montmorillonite and phillipsite are the alteration products of basaltic glass. Most of the samples contain less than 10 percent montmorillonite. The presence of phillipsite

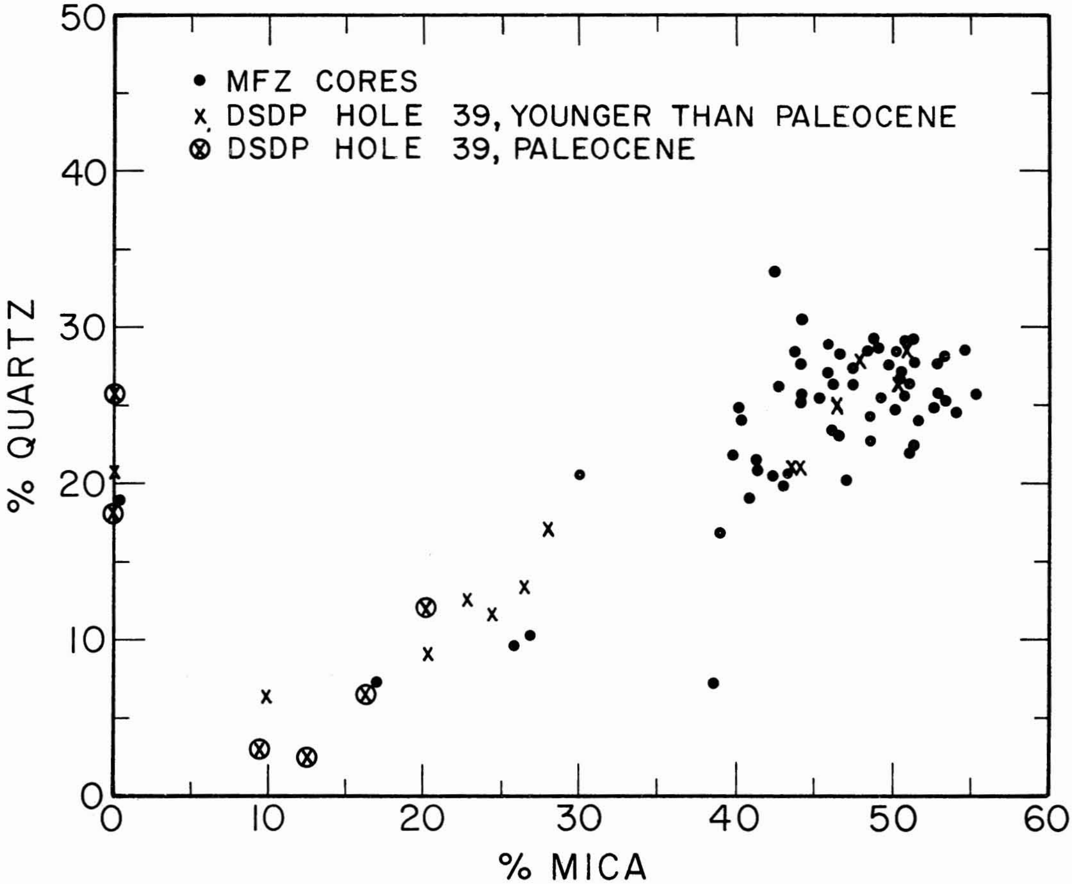

FIGURE 3. Scatter plot of quartz versus mica of the DSDP Hole 39 and MFZ cores.

is usually correlated with the absence of plagioclase and kaolinite and is common in areas of slow sedimentation and absence of detrital minerals. High concentrations of phillipsite are commonly present at the top of the cores. Czyscinski (1973) demonstrated that nucleation of phillipsite occurs at the sediment–seawater interface and there is no additional crystal growth below 1–2 m depth in the sediment. The phillipsite of DSDP Hole 39 probably was originally located at the old sediment–seawater interface and later was buried by pelagic sediments.

Goethite and hematite, reported in small amounts in shallow bays around the Hawaiian Islands, are not found in deeper sea-floor areas there (Fan 1976). The minute amount of iron oxides coating brown clays is below the limit of detection by X-ray diffraction ($<1/2$ percent). The high concentration of goethite found in DSDP Hole 39 is not detrital; Von der Borch and Rex (1970) suggest that it precipitated from hydrothermal sources, as has been reported in the East Pacific Rise (Bostrom and Peterson 1966), the Red Sea (Bischoff 1969), and other DSDP sites. The close relationship of K-feldspar, higher concentrations of kaolinite, and goethite suggest that K-feldspar and some kaolinite also may be derived from hydrothermal sources.

In summary, the brown clays in the vicinity of the Murray Fracture Zone are dominated by eolian quartz and mica, with authigenic phillipsite common at the sediment–water interface. The plagioclase and augite came from submarine volcanic rocks. Kaolinite is a detrital mineral derived from the land. The hydrothermal assemblages near Necker ridge (MFZ 3–5) are significant in that they are characterized by the presence of euhedral dolomite as has been reported by Bonatti (1966) in the South Pacific. The lower portion of the cores from DSDP Hole 39 is also considered to be a hydrothermal assemblage.

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